SENSOR DATA HANDLING BY PERSONAL COMPUTER

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ABSTRACT

An eight channel sensor data acquisition and processing system has been built and tested. The hardware, built on an IBM PC AT interface board, contains a multiplexed A/D converter and board memory. Fully menu-driven software, written in C language, selects the necessary hardware parameters and initiates a DMA transfer of the sampled data and provides an option for selection of processing algorithm. Sensor calibration and correlation computation algorithms have been incorporated as part of processing algorithms.

INTRODUCTION

Multi-channel data acquisition and processing has been an active working area in the past few years and much work has been done to cater for specific needs in industry. In the early days, advantaged of a computer were not fully exploited and the systems were mainly of acquisition type. Parallel with the development of fast processors, the trend has changed towards data acquisition and processing in which useful signal processing algorithms are implemented even in real time.

The need for processing arises in various situations particularly in environments where sensors are involved for measurement or control purpose. For example the non-linear input/output characteristics of the sensors must be eliminated, or at least minimized, either by software or hardware techniques in order to have a one to one relationship between the actual variable and the electrical output. The main disadvantage of hardware linearization is the need for different circuits for different sensors. The other common application of processing is in indirect method of measurement where part of the procedure is some kind of computation. A good example is determination of flow rate using correlation technique which involves flow rate measurement at two points separated by a distance and computation of correlation in order to obtain the peak value.

The main objective of this project was to integrate processing algorithms with an eight channel sensor data acquisition system. The hardware problem could be solved either by ready-made data acquisition boards or by a custom designed system suitable for specific applications. The later approach has been taken as it was part of the requirement.

HARDWARE DESCRIPTION

Fig 1 shows the hardware configuration which was built on an IBM VERO interface card. The main sub units are multiplexed analog to digital convertor, first-in-first-out (FIFO) board memory, and a control unit.

The control unit consists of an address decoder, programmable interval timer, digital 2-1 selector, and some logic gates. The address allocated for interface board is decoded by the control unit to select a maximum of eight different operations. The purpose of the programmable timer is to generate a sampling clock which by dividing the CPU clock using a user selected factor, and to count the number of samples.

The operation of the system is as follows: Parameters like sampling frequency, number of channels, and number of samples per channel are entered from the keyboard. Upon a start command, the selected channels will be sampled and stored at contiguous memory locations. If data is found useful transfer from board memory to the hard disk will be performed.

In designing the system, two types of data transfer to the computer memory have been considered. In the first type where a lot of data transfer is necessary, direct memory access (DMA) was applied where channel-1 of the computer DMA controller was initialized and took care of the transfer. In the second type, a simple processor assisted transfer, that is programmed I/O, has been included for relatively low sample size.

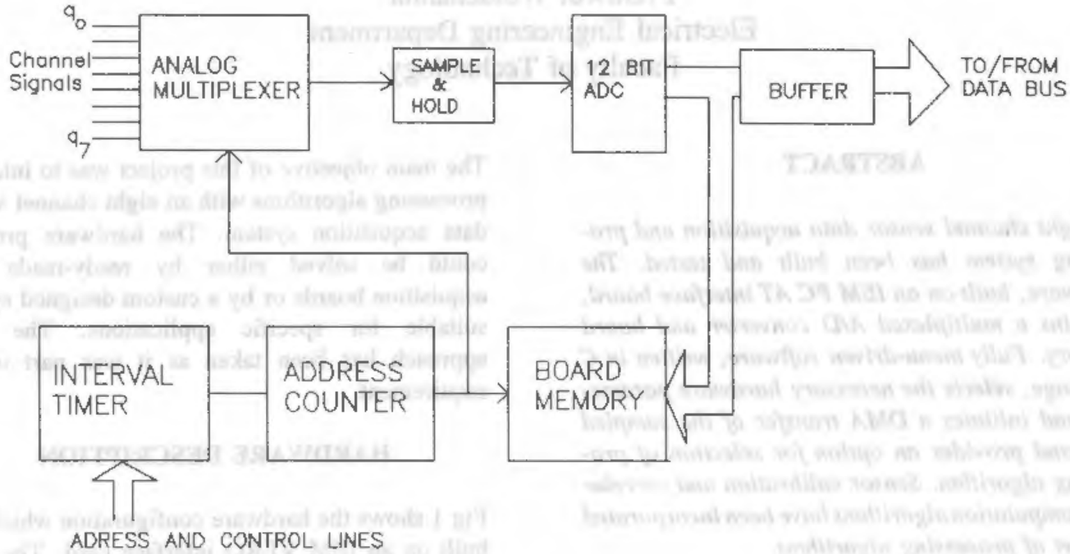

Figure 1 Block Diagram of Interface System

DATA PROCESSING ALGORITHMS

Different types of algorithms may be required for different applications. The algorithms included for this project are calibration and correlation computation. A review of the supporting equations for the three algorithms is given below.

Calibration

The relationship between a sensor output and the primary variable to which the sensor is supposed to respond must be obtained before any interpretation of data. The procedure by which this relationship is determined is what is known as calibration. In the present work discrete input values are read in increasing and decreasing modes. If the hysteresis, that is the difference between the loading and unloading characteristics, is significant, two separate least square fit lines are determined for subsequent use. Otherwise, an average least square fit is considered sufficient.

Given N measurement points (x_i,y_i), $i=1,..,N$, the least square fit is described by the linear equation:

$$y=ax+b$$

where

$$a=\frac{\sum y_i\sum x_i-N\sum x_iy_i}{(\sum x_i)^2-N\sum x_i^2}$$

and

$$b=\frac{\sum y_i-a\sum x_i}{N}$$

The above equation is applied on the average ordinates (for negligible hysteresis) or the loading and unloading ordinates separately.

Correlation

The cross-correlation function for two signals X and Y indicates the degree of similarity between the two waveforms, since the time average of the product will exist only if the two functions go positive or negative together.

If X and Y are identical, then the cross-correlation function becomes the autocorrelation function. The important properties of correlation function may be listed as follows.

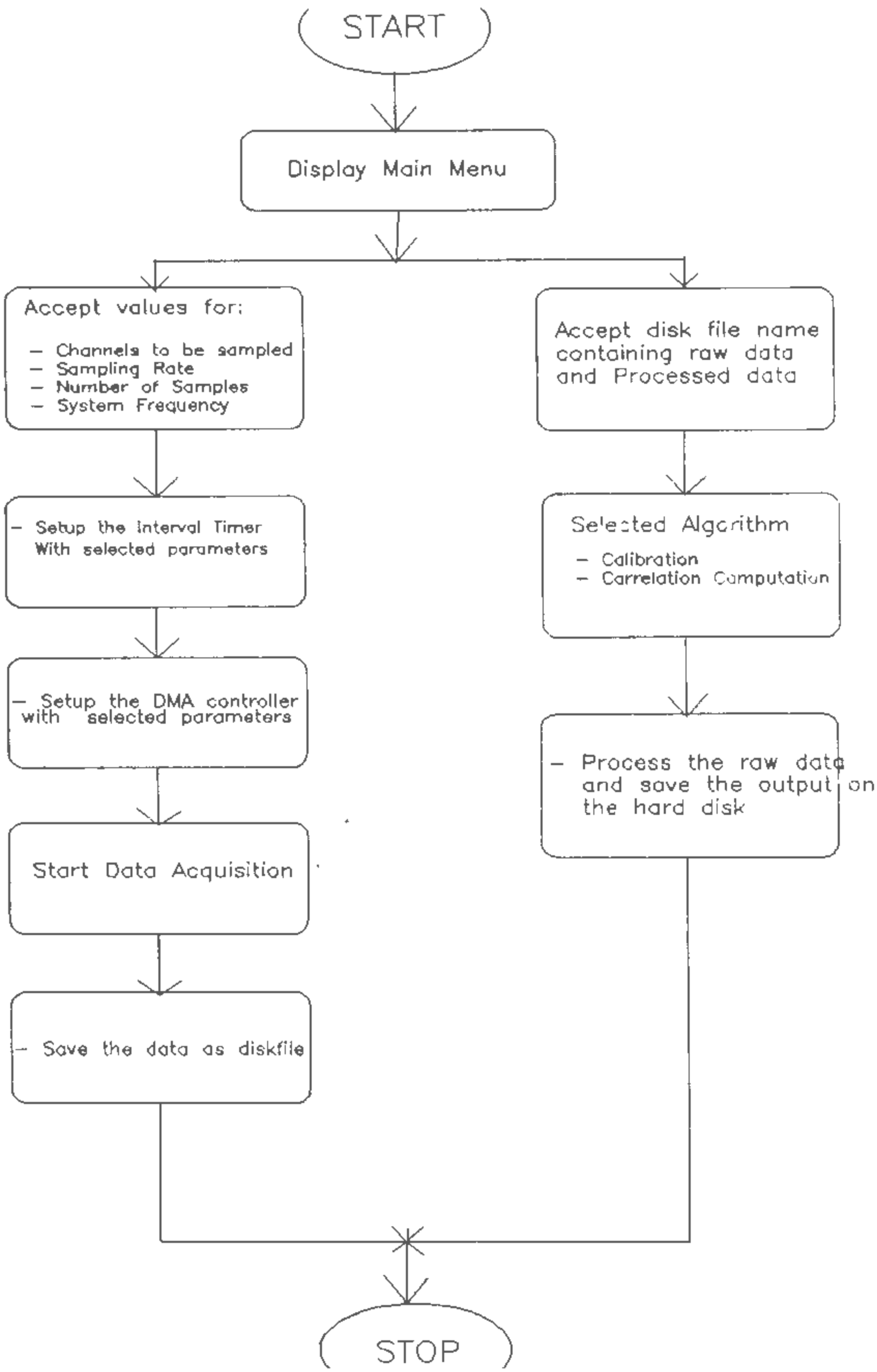

Figure 1.2 Flow Chart of the Driver Software

$$R_{xy}(\tau) = \begin{cases} \int_{-\infty}^{\infty} x(t)y(t+\tau)dt & : \text{Continuous time} \\ \sum_{k=-\infty}^{\infty} x_k y_{k+\tau} & : \text{Discrete time} \end{cases}$$

(a) $R_{xx}(\tau)=R_{xx}(-\tau)$, that is, it is an even function of τ,

(b) $R_{xx}(\tau)$ attains its maximum at $\tau=0$,

(c) If X is periodic, then $R_{xx}(\tau)$ is also periodic,

(d) If X is random then $R_{xx}(\tau)$ approaches zero for very large τ,

(e) If X and Y are uncorrelated then the autocorrelation of the sum will be the sum of the autocorrelation of each component.

A good example of the use of cross-correlation is found in fluid flow rate or fluid velocity measurement. For this two flow sensors are placed at two points along the fluid whose velocity is to be measured. The cross-correlation coefficient will be maximum when the variable delay equals the time for a point on the fluid to travel a distance equal to the separation between the sensors. The fluid velocity would then be $v = d/\tau$. For adequate accuracy, d must not be too large so as to restrict the period of correlation required to get a distinct peak in the correlation function. On the other hand, d must not be too small to make its determination difficult.

Cross correlation requires a reference signal which in most cases is similar to signal to be recovered. Hence the method is unsuitable for detection of unknown signals. However, for detecting unknown periodic signals, autocorrelation proves more convenient.

SOFTWARE DESCRIPTION

The driver software has been developed to fulfil two requirements; to address the interface board and accept samples either in DMA mode or sample by sample basis and to accommodate processing algorithms on the raw data.

The main board address is divided into eight subaddresses via a second 3-8 decoder so that desired selection is made simply by writing at or reading from the specific address.

The overall program is organized into a number of modules each with its own task: PIT Set-Up Module, DMA Set-up Module, Calibration Module, Correlation Module, and so on. The flow-chart is shown in figure 1.2.

CONCLUSION

The system built was tested with two sensors: a thermocouple and a strain gauge. The results were quite satisfactory and promising to add more features into the system. The processing part can be expanded by including additional algorithms suitable for the application under interest.

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